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A study on the operating costs of a locally manufactured floating pump station

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KEY WORDS:
Centrifugal pump; diesel engine performance, floating pumping station, fuel consumption, operating cost analysis;

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ABSTRACT

This study experimentally evaluated the fuel consumption and operating costs of a locally manufactured diesel-powered floating pumping station designed for operation under low river water levels in Iraq. The system consists of four pontoons supporting a centrifugal pump (Rovatti 5″ × 6″) driven by a 51 kW DEUTZ diesel engine. A factorial experiment was conducted in 2024 using three water depths (2, 2.5, and 3 m), three pump speeds (1500, 1600, and 1700 rpm), and three discharge pressures (2.5, 3.0, and 3.5 bar) with three replications in a completely randomized design. Fuel consumption was measured in $L \cdot h^{-1}$ and economic analysis was performed to estimate fixed, variable, and total operating costs ($ID \cdot h^{-1}$). The results showed that pump speed significantly affected fuel consumption and total operating costs ($p \leq 0.05$). Increasing speed from 1500 to 1700 rpm increased fuel consumption from 5.14 to 11.49 $L \cdot h^{-1}$, leading to a substantial rise in hourly operating costs. Discharge pressure also influenced fuel consumption, whereas water depth had no significant effect within the tested range. The lowest total operating cost was achieved at 1500 rpm under 3.5 bar discharge pressure. Economic analysis indicated that fuel costs constituted the largest proportion of total variable costs. The findings demonstrate that operating the floating pumping station at moderate engine speeds enhances fuel efficiency and reduces operational expenses. The study provides practical guidelines for optimizing the economic performance of floating pumping systems under fluctuating river water levels.

دراسة تكاليف التشغيل لمحطة الضخ العائمة المصنعة محليا

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الخلاصة

ادت هذه الدراسة بتقييم استهلاك الوقود وتكاليف التشغيل لمحطة ضخ عائمة تعمل بالديزل، مصنعة محليًا، ومصممة للعمل في مستويات منخفضة من مياه الأنهار في العراق. يتكون النظام من أربعة عوامات تدعم مضخة طرد مركزي (Rovatti) (5 بوصة × 6 بوصة) تعمل بمحرك ديزل من نوع DEUTZ بقدرة 51 كيلوواط. أُجريت تجربة عاملية في عام 2024 باستخدام ثلاثة أعماق للمياه (2، 2.5، و3 أمتار)، وثلاث سرعات للمضخة (1500، 1600، و1700 دورة في الدقيقة)، وثلاثة ضغوط تصريف (2.5، 3.0، و3.5 بار) مع ثلاث تكرارات في تصميم عشوائي كامل. تم قياس استهلاك الوقود باللتر/ ساعة، وأُجري تحليل اقتصادي لتقدير تكاليف التشغيل الثابتة والمتغيرة والإجمالية (دينار/ ساعة). أظهرت النتائج أن سرعة المضخة تؤثر بشكل كبير على استهلاك الوقود وتكاليف التشغيل الإجمالية .($p \leq 0.05$) أدى رفع سرعة المحرك من 1500 إلى 1700 دورة في الدقيقة إلى زيادة استهلاك الوقود من 5.14 إلى 11.49 لتر/ساعة، مما تسبب في ارتفاع ملحوظ في تكاليف التشغيل بالساعة. كما أثر ضغط االدفع على استهلاك الوقود، بينما لم يكن لعمق الماء تأثير يُذكر ضمن النطاق المختبري. وقد تحققت أدنى تكلفة تشغيل إجمالية عند 1500 دورة في الدقيقة تحت ضغط تصريف 3.5 بار. وأشارت التحليلات الاقتصادية إلى أن تكاليف الوقود تُشكل النسبة الأكبر من إجمالي التكاليف المتغيرة . تُبين النتائج أن تشغيل محطة الضخ العائمة بسرعات محرك معتدلة يُحسّن كفاءة استهلاك الوقود ويُقلل من نفقات التشغيل. وتُقدم هذه الدراسة إرشادات عملية لتحسين الأداء الاقتصادي لأنظمة الضخ العائمة في ظل تقلبات مستويات مياه الانهر.

الكلمات الافتتاحية : اداء المحرك الديزل ، المضخات الطاردة المركزية ، استهلاك الوقود،تحليل تكاليف التشغيل، محطة ضخ عائمة.

INTROUCTION

Due to the climatic conditions experienced by many countries, which have led to global warming and its consequences, including a noticeable increase in temperatures and water scarcity, Iraq has faced a significant decline in the water levels of its rivers. To address the issue of the inability to draw water from rivers with reduced levels using the existing fixed pumping stations on riverbanks, a concept was developed to design and manufacture a floating water pumping station. This station is capable of drawing water from rivers regardless of how low the water level may be (it can draw water when the river level is as low as 65 cm). The station floats on the water, rising and falling with the water level, allowing it to draw water and subsequently deliver it to the riverbank (ensuring stable NPSH). From there, the water can be lifted to the riverbank, canals, or storage tanks for use in agriculture, industry, or civil purposes. Several tests were conducted on this floating pumping station, demonstrating its effectiveness (Al-Obaidi. 2023).

Cost considerations are crucial in selecting any industrial product, and many farmers express concerns about operational costs in general and fuel consumption in particular when using equipment powered by diesel engines. This study was conducted to provide farmers with a comprehensive understanding of the overall cost indicators of a floating pumping station and to encourage its adoption. To assess its performance indicators, it was necessary to study the operating costs and fuel consumption since it is powered by a diesel engine. Al-Bakri, & &Kazim, 2016).

The study aims to evaluate the operating costs of the floating pumping station to improve its operational efficiency and enhance its performance, ultimately achieving maximum productivity with the lowest possible costs. (Al-Badri *et al*. 2020) highlighted that the optimal selection of centrifugal pumps according to water needs and varying river levels can reduce horsepower requirements, thereby lowering direct costs. Economic costs are defined as the

expenses incurred from operating agricultural machinery and equipment, which are a primary factor in evaluating the performance of these machines. It is preferable to select machines and equipment that yield the highest output with the lowest operating costs (Al-Aani. 2024) Fuel consumption can be described as the volume of fuel injected into the combustion chamber of internal combustion engines, mixed with oxygen to aid combustion, and is measured in units of liters per hour ($L \cdot h^{-1}$).

Studying economic costs is crucial for obtaining information that enables us to make informed decisions regarding the use of agricultural machinery and equipment. This involves understanding the income generated from their operation in relation to the known costs associated with that work. The primary goal of most agricultural researchers is to reduce agricultural production costs (A. Alwash). Economic costs are categorized as follows:

Economic Costs = Fixed Costs + Variable Costs + Administrative Costs

However, despite the development of floating pumping systems, limited studies have evaluated the economic performance of such systems under variable operational conditions. Therefore, this study aims to fill this gap by experimentally assessing the relationship between pump speed, discharge pressure, water depth, fuel consumption, and total operating cost.

MATERIALS AND METHODS

A factorial experiment was conducted with three replications, following a Complete Randomized Design (CRD). The significant differences between means were compared using the Least Significant Difference (LSD) test at a 0.05 significance level. The statistical analysis of the data was performed using the GenStat software. The experiment took place in 2024 at the University of Baghdad / University Presidency / Department of Administrative Affairs – Raw Water Pumping Station Basins. The study focused on evaluating the economic costs of a floating pumping station powered by a diesel engine. The treatments included:

Water Depth: Three levels (2, 2.5, and 3 meters).
Speed: Three levels (1500, 1600, and 1700 rpm).
Discharge Pressure: Three levels (2.5, 3, and 3.5 bar).

General Description of the Floating Pumping Station Used in the Experiment:

The floating pumping station used in the experiment was locally designed and manufactured based on precise engineering diagrams and measurements. It includes a (5" × 6") Ruvatti centrifugal pump (model F34P150KAN-SP, Italian-made, 2011) and a DEUTZ diesel engine with a power rating of 51 kW (69 horsepower, German-made). The station's structure comprises a metal foundation, pontoons for buoyancy, suction and delivery pipes, and a delivery valve for flow control. It is equipped with a pressure gauge for monitoring pressure, a foot valve to prevent backflow, and a grid base for stability. Additional components include a metal fence, a strainer to filter out debris, and steel wire rope for enhanced support (Figure 1 and 2).

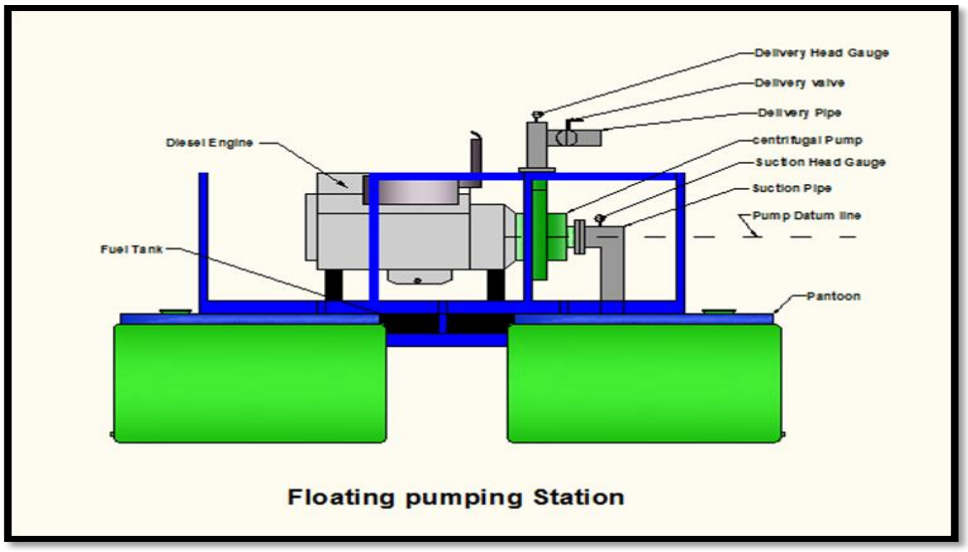

Figure (1) shows a schematic diagram depicting a side view of the floating pumping station (Al-Obaidy. 2023).

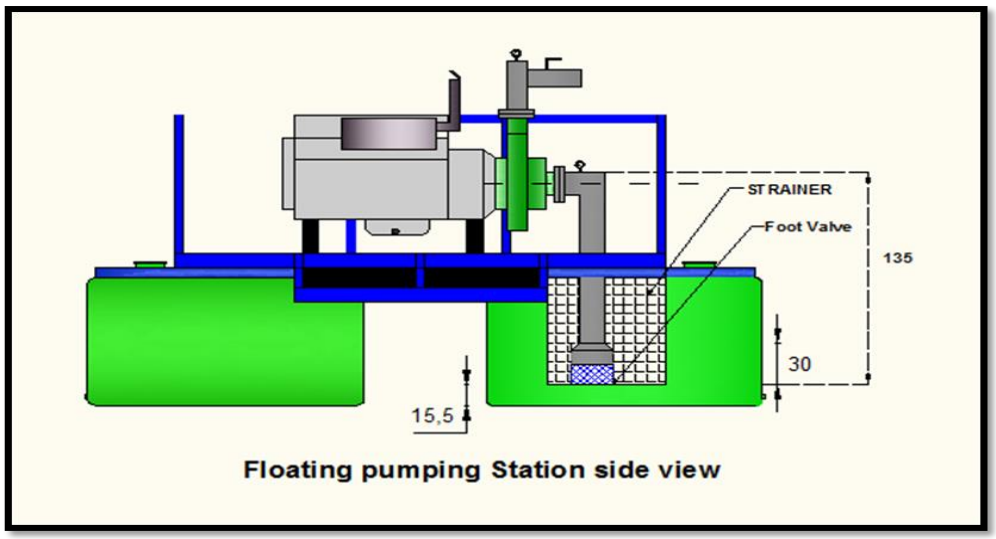

Figure (2) shows a schematic diagram depicting a side view of the suction pipe location, which aids in drawing water at a low level (Al-Obaidy. 2023).

Installation of the floating pumping station and conducting tests and research completion

After assembling the floating pumping station with all its components and accessories, and ensuring the proper tension of bolts and checking the welding areas, the station was lifted and transported using a self-propelled crane to the testing site at the University of Baghdad Presidency / Department of Administrative Affairs – Raw Water Pumping Station Basins. The station was secured to the basin wall with a metal wire to prevent drifting. The tests were conducted according to the specified parameters to study and assess performance indicators (Figure 3).

Figure (3) shows the floating pumping station in operation (Al-Obaidy. 2023).

Studied Parameters and Their Calculation Methods:

1. **Fuel Consumption ($L \cdot h^{-1}$):**

The fuel used in this study to operate the diesel engine is pure conventional diesel produced by the Iraqi Ministry of Oil (Al-Doura Refinery). A locally manufactured device was used to measure the fuel consumption of the diesel internal combustion engine. Fuel consumption was calculated based on the specified water depths, speeds, and discharge pressures in the experiment, with three replications. This was done using a graduated cylinder (burette) with a volume capacity of 1000 milliliters, which was supplied with fuel from an external tank. The time was recorded using an electronic timer (Figure 4) (Al-Azzawi,. & Firas 2025).

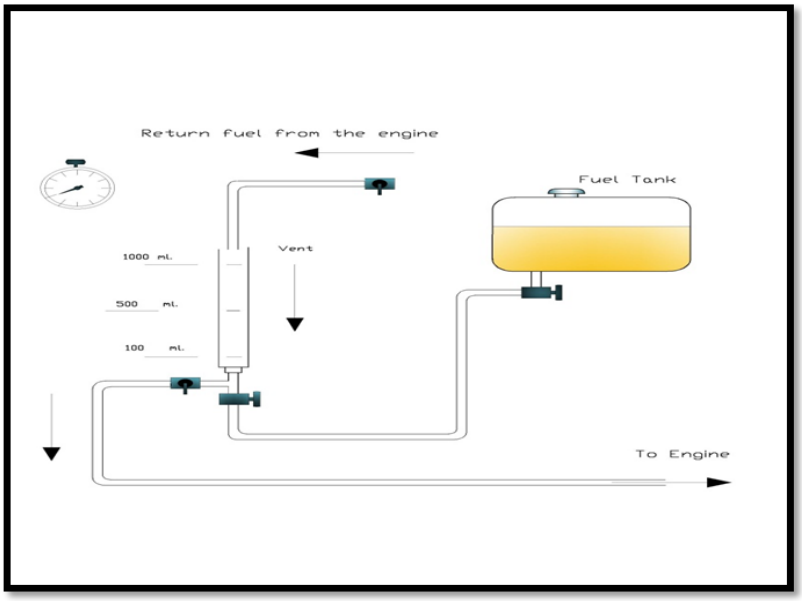

Figure (4) Fuel consumption measurement device (Al-Obaidy. 2023).

Costs:

The costs were calculated and classified as follows:

First – Fixed Capital Costs:

These include the amounts spent on manufacturing the floating pumping system as detailed below:

- The cost of purchasing the pumping unit (diesel engine with a centrifugal pump) and its accessories, including the fuel tank and electronic control panel.
- The cost of purchasing the metallic materials for the fabrication of the system.
- The cost of purchasing accessories for the floating pumping station (pressure gauges, connections, fastening tools, rubber gaskets, discharge measurement device with its filter, non-return valve, grating, metal wire, and ties).
- The cost of manufacturing in local markets.
- The cost of assembly.
- The cost of applying epoxy coating for moisture resistance.
- The cost of transportation and installation at the worksite.

The fixed capital was calculated in Iraqi dinars according to the prevailing prices in Iraqi local markets for the year 2024.

Second: Fixed Costs

These costs are not dependent on whether the system is operational or not. The total costs were calculated using the method followed by Al-Tahan *et al*.(1991), as detailed below:

1. **Depreciation:**
   The depreciation value is calculated using the straight-line method as per the following equation:
   Dep. = (P - S) / L …….(1)

Where:

Dep. = Depreciation, in dinars per hour.

P = Purchase price of the system, in dinars.

S = Sale price of the system when fully depreciated, calculated as 10% of the system's purchase price, in dinars.

L = Time between purchase and sale, in hours.

The system's useful life in hours is calculated based on the annual operational time multiplied by the system's operational lifespan.

2. Interest Costs on Capital:

The interest is estimated at 10% of the system's purchase price and can be calculated using the following equations:

- **Int. = P × 0.1** …….(2)
- Alternatively, it can be calculated as:
  Int. = ((P + S) ÷ 2) / L × 0.1 ……..(3)

Where:

Int. = Interest on capital, in dinars per hour.
P = Purchase price of the system, in Iraqi dinars.
S = Sale price of the system, in Iraqi dinars.
L = Annual operating time.
0.1 = Interest rate, expressed as a percentage (10%).

3. Taxes, Shelter, and Insurance:

These costs are estimated at around 4% of the system's purchase price and can be calculated using the following equation:

- **T.S.I. = P × 0.04** …….(4)

Alternatively, they can be calculated as:

- **T.S.I. = (P / L) × 0.02** ……..(5)

Where:
T.S.I. = Taxes, shelter, and insurance costs, in dinars per hour.
P = Purchase price of the system, in dinars.
L = Annual operating time.
2% = The percentage value for taxes, insurance, and shelter.

4. Fixed Costs of the System:

The fixed costs are calculated using the following equation:

- **F.C. = Dep. + Int. + T.S.I.** ……(6)

Where:
F.C. = Fixed costs, in dinars per hour.
Dep. = Annual depreciation, in dinars per hour.
Int. = Interest on capital, in dinars per hour.
T.S.I. = Taxes, insurance, and shelter costs, in dinars per hour.

Third – Variable Costs:

Variable costs include fuel costs, oils, lubrication, maintenance, repairs, and labor costs. It is worth noting that the floating pumping station under study does not have lubrication points, as the pump is self-lubricating. These costs are directly related to the operation of the system.

1. **Fuel Costs:**
   A locally manufactured device was used to measure the fuel consumption of the internal combustion engine (refer to Figure 3). The following equation, proposed by Ismail (2001), was used to calculate fuel costs:

Fu.c. = fu.co. (L/h) × Fu.p. (ID/L) = ID/h ……..(7)

Alternatively, it can also be calculated using:

Fu.c. = Bhp × 60% × 25% × Fu.p. ……..(8)

Where:
Fu.c. = Fuel costs, in dinars per hour.
Bhp. = Brake horsepower, in horsepower (hp).
Fu.p. = Purchase price of one liter of fuel, in dinars per liter.

2. Lubricating Oil and Grease Costs:

Lubricating oil costs are neglected when using electric engines; however, for internal combustion engines, they are calculated as follows:

- One liter of oil is used for every 50 liters of fuel consumed by the engine.
- Alternatively, oil costs can be estimated at approximately 15% of fuel costs.
- The oil cost can also be calculated using the following equation:
  Oil.C. = Bhp × 0.03 × 25% × 60% × Fo …….(9)

Where:

Oil.C. = Oil costs, in dinars.

Bhp. = Brake horsepower, in horsepower (hp).

Fo = Purchase price of one liter of oil, in dinars.

3. Maintenance and Repair Costs:

Maintenance and repair costs can be calculated using the following equation:

M.R. = (P × 4.5%) / L ……..(10)

Where:

M.R. = Maintenance and repair costs, in dinars per hour.

P = Purchase price of the system, in dinars.

L = Annual operating hours.

4. Labor Costs (Operator Wages):

Labor costs are calculated using the following equation:

L.C. = Sa / Op ……..(11)

Where:

L.C. = Labor costs, in dinars per hour.

Sa = Operator's daily wage, in dinars per day.

Op = Daily operating time, in hours per day.

The total variable costs are calculated as follows:

V.C. = Fu.c. + Oil.C. + M.R. + L.C. …….. (12)

Where:

V.C. = Variable costs, in dinars.

Fu.c. = Fuel costs, in dinars.

Oil.C. = Oil costs, in dinars.

M.R. = Maintenance and repair costs, in dinars.

L.C. = Labor costs, in dinars.

Fourth: Overhead Cost:

The overhead costs are calculated using the following equation: **OHC = (F.C. + V.C.) × 0.10** ..(13)

Where:

OHC = Overhead costs, in dinars.
F.C. = Fixed costs, in dinars.
V.C. = Variable costs, in dinars.
Fifth: Total Operating Costs: The total operating costs are calculated using the following equation:

Total Operating Costs = Fixed Costs + Variable Costs + Overhead Costs

$$T.O.C. = F.C. + V.C. + OHC \quad \text{……..(14)}$$

Where:
T.O.C. = Total operating costs of the system, in dinars per hour.
F.C. = Fixed costs.
V.C. = Variable costs.
OHC = Overhead costs.
(Alazzawi & Al-Aani. 2025)

Experiment Implementation:
After securing the floating pumping station at the required depth for the study, the diesel engine is initially run at a low speed for five to ten minutes to stabilize it. The speed is then gradually increased until reaching the first test speed (1500 rpm), as determined by a tachometer. The discharge valve is manually and gradually adjusted to set the first discharge pressure (2.5 bar) for the pump, and then the fuel consumption measurement device is used. This process is repeated for other speeds, discharge pressures, and depths, with three replications to minimize experimental error. After measuring fuel consumption, the relevant cost equations are applied.

RESULT AND DISCUSSION

Figure (5) illustrates the effect of water depth, pump speed, and discharge pressure on fuel consumption. The highest fuel consumption was recorded when the water depth was 2 meters, the pump speed was 1700 rpm, and the discharge pressure was 2.5 bar, reaching 11.49 $L \cdot h^{-1}$. This increase is attributed to the fact that higher engine speeds require additional power, leading to increased fuel consumption (Kazim. 2013). Conversely, the lowest fuel consumption was observed when the water depth was 3 meters, the speed was 1500 rpm, and the discharge pressure was 3.5 bar, with a consumption of 5.14 $L \cdot h^{-1}$. This reduction is due to the lower engine speed. These findings are consistent with the results obtained by (Trinath & Amitabh 2009)& (Kim and Park, 2016).

Figure (6) shows the effect of water depth, pump speed, and discharge pressure on fuel costs. The highest fuel costs were recorded when the water depth was 2 meters, the pump speed was 1700 rpm, and the discharge pressure was 2.5 bar, reaching 4594.7 dinars per hour. In contrast, the lowest fuel costs were observed with the combination of a 3-meter water depth, a speed of 1500 rpm, and a discharge pressure of 3.5 bar, amounting to 2056 dinars per hour.

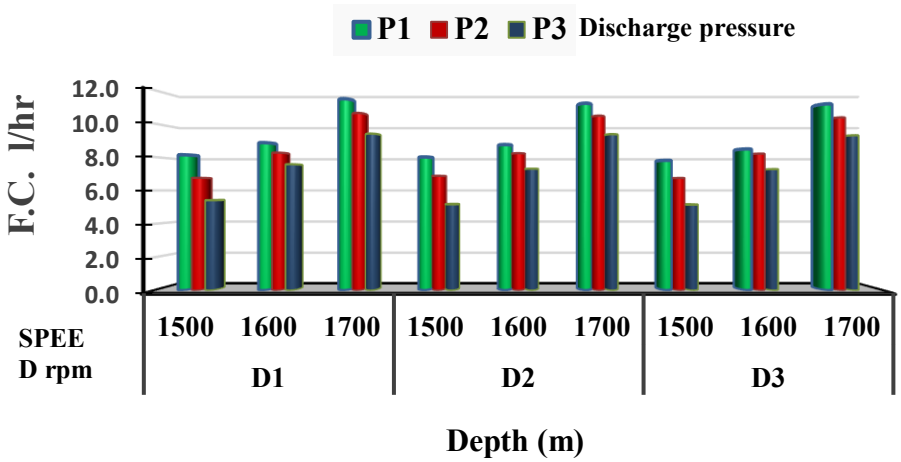

Figure 5. shows the effect of water depth, pump speed, and discharge pressure on fuel consumption ($L \cdot h^{-1}$). (Al-Obaidy. 2023).

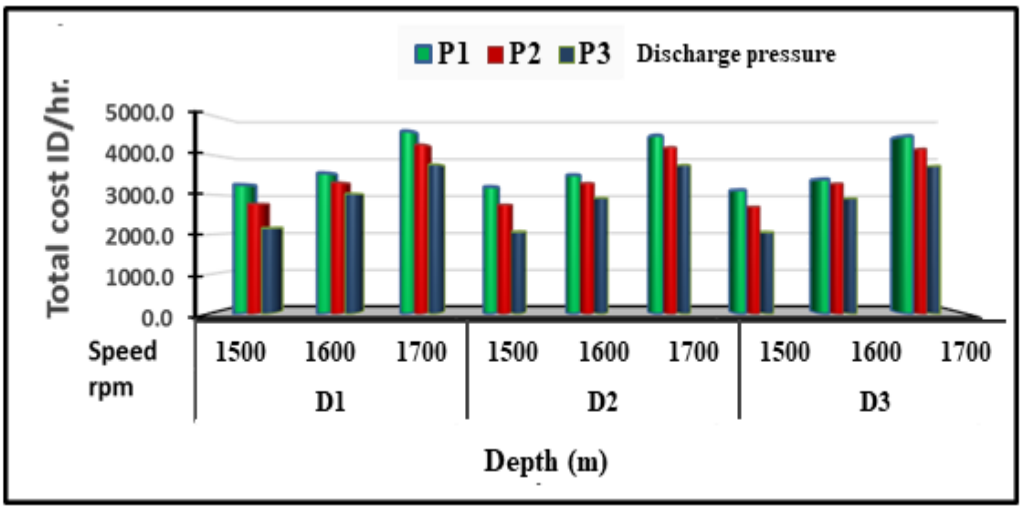

Figure 6. Shows the effect of water depth, speed, and discharge pressure on fuel costs (dinars$\cdot h^{-1}$). (Al-Obaidy. 2023).

Only the fuel cost (ID$\cdot$ h^{-1} of operation) was included in the statistical analysis since diesel fuel consumption for operating the floating pumping station is influenced by changes in speed, discharge pressures, and practical operating conditions, such as ambient air temperature(Martyna, *et al* , 2021, Świętochowska *et al*., 2021), water density, and the fuel's temperature. The other cost components are not affected by the operation of the floating pumping station. The official fuel price set by the Iraqi Ministry of Oil, which is 400 dinars per liter, was used. Subsequently, the remaining costs (total costs) were calculated.

Table (1) presents the values of the operating costs for the floating pumping station in ID$\cdot h^{-1}$, broken down by cost components and based on the station's operation at each speed. The analysis assumes that the floating pumping system operates with the discharge valve open (i.e., the system operates at a discharge pressure of 2.5 bar). It was assumed that the floating pumping system operates for five hours per day.

Table 1. Operating cost values of the floating pumping station (ID·h⁻¹).

Category				
1	Fixed Capital Costs	17,000,000IQD		
2	Useful Life	15years		
3	Operating Rate	5 hours day^{-}	1,825 hours year^{-1}	
Fixed Costs (ID houre^{-1})				
1	Depreciation	559		
2	Interest on Capital	512		
3	Taxes, Insurance, and	186		
	Total Fixed Costs	1257		
Variable Costs (ID houre^{-1})				
		1500 rpm	1600 rpm	1700 rpm
1	Average Fuel Costs at	3191	3477	4518
2	Lubricating Oil Costs	478	521	677
3	Maintenance and	419	419	419
4	Labor Costs	3750	3750	3750
	Total Variable Costs	7838	8167	9364
Administrative Costs				
	971			
Total Operating Costs (ID h^{-1} operation				
1	1500 rpm	10000		
2	1600 rpm	10400 ~ 10385		
3	1700 rpm	11600 ~11592		

CONCLUSION

The design and manufacture of the floating pumping station powered by a diesel engine proved successful in performing its function of drawing water from low levels and delivering it to the riverbank. It demonstrated moderate fuel consumption compared to other agricultural equipment, along with reasonable economic costs. The station's quality construction ensures a long operational lifespan and a high safety factor against sinking and vibrations, thanks to the presence of four pontoons, which reduce the risk of sinking in case one of them is damaged.

Recommendations

We recommend that farmers with medium-sized agricultural holdings use the floating pumping station when river water levels are low, as its success has been proven. We recommend that government agencies use the floating pumping station to supply residential areas with water when river water levels are low. We recommend operating the floating pumping station at a speed of 1500 rpm to minimize economic costs, extend its operational life, and reduce maintenance expenses.

CONFLICT OF INTEREST

The author declare they have no financial interests.

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